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Original

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Electrophoretic deposition of Sr-containing mesoporous bioactive glass particles produced by spray-drying

G. Molino^a, S. Fiorilli^a, A. Bari^a, F. Baino^a, C. Vitale-Brovarone^a

^a Politecnico di Torino, Department of Applied Science and Technology,
Corso Duca degli Abruzzi 24, 10129 Turin, Italy

chiara.vitale@polito.it



Introduction

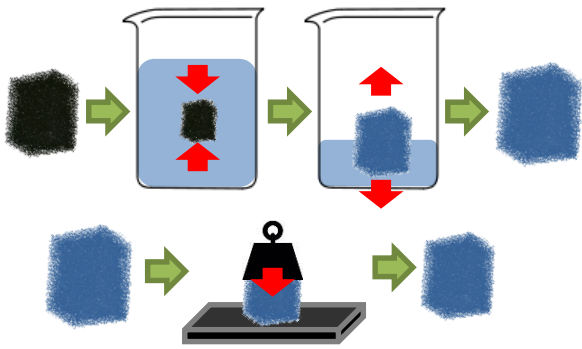
Mesoporous bioactive glasses (MBGs) have exceptional biological and textural characteristics (high surface area, high pore volume and highly ordered mesoporosity), which allow these glasses to be successfully applied in bone tissue regeneration [1]. In this work we adopted an **aerosol-based spray-drying synthesis** to obtain MBG particles doped with **strontium (SD_Sr-MBG)**, element known for its osteogenic and bone antiresorptive properties [2]. Later these particles have been deposited by **electrophoretic deposition (EPD)** on almost **biologically inert glass-ceramic scaffolds** (SCNA; 57SiO₂–34CaO–6Na₂O–3Al₂O₃ %mol.) fabricated by the polymer sponge replication method [3], in order to transfer their bioactive behavior to scaffolds and consequently to obtain an excellent solution for bone tissue regeneration.

Spray-drying synthesis of SD_Sr-MBG



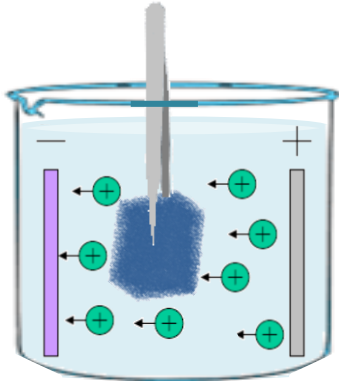
- Pluronic P123, used as template, is dissolved in **bidistilled water**
- Tetraethyl orthosilicate (TEOS) is hydrolysed under **acidic conditions** (pH adjusted to 2)
- Mixing of the two solutions
- Addition of **strontium chloride** and of calcium nitrate tetra-hydrate (**CaNT**)
- Spraying of the final synthesis solution (**pH ~ 3.5**)
- The powder is calcined in air at **600 °C** for **5 h**

SCNA scaffold preparation



- PU cubic sponges (10 x 10 x 10 mm) are immersed in a **SCNA slurry** (57SiO₂– 34CaO– 6Na₂O–3Al₂O₃ mol.%)
- **SCNA:PVA:distilled water = 30:6:64 wt%**
- The PU template is extracted from the solution and **compressed** (50 kPa for 1 s) up to **60%** in thickness along three orthogonal spatial directions 3 times.
- Scaffolds are dried at RT overnight and after treated at **1000°C** for **3 h**

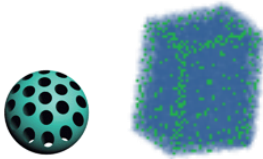
EPD process



| EPD parameter | Value |
|--------------------------------|-------------------------|
| Solvent | Ethanol |
| Dispersant concentration (TEA) | 2,5 g/l |
| SD_Sr-MBG concentration | 4 g/l |
| Voltage | 120 V, 150 V, 180 V |
| Duration | 5 min |
| Electrodes separation | 15 mm |
| Electrodes material | Stainless steel |
| Electrodes dimensions (HxLxT) | 40 mm x 15 mm x 0,35 mm |

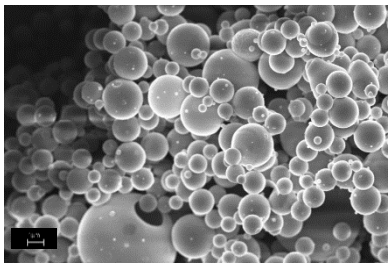
MBG particles and scaffolds characterization

- Morphological and chemical analysis (FESEM, EDS, nanoCT)
- Textural analysis (adsorption and desorption of N₂, laser diffraction and UV-VIS absorbance spectroscopy)
- Strontium release test in SBF
- Bioactivity test in SBF

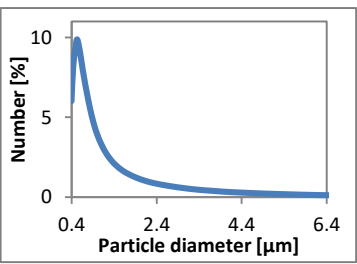


Results and discussion

SD_Sr-MBG particles

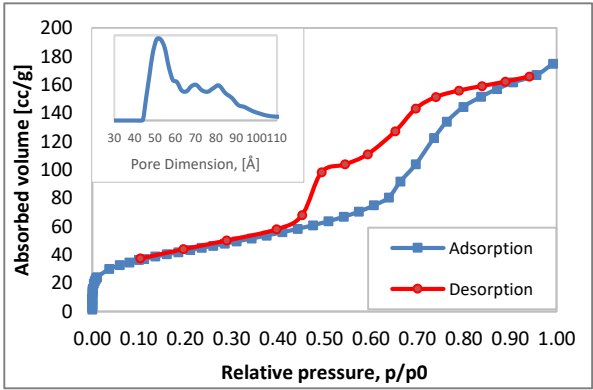


FESEM image: particles have a perfect **spherical shape**.

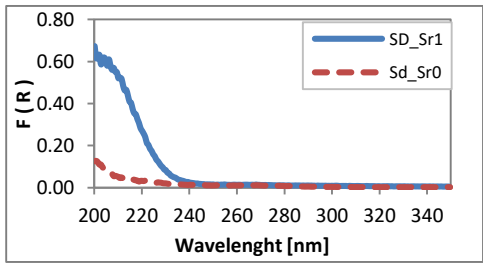


Most of particles have diameter **below 2 μm**. Few reach 5 μm.

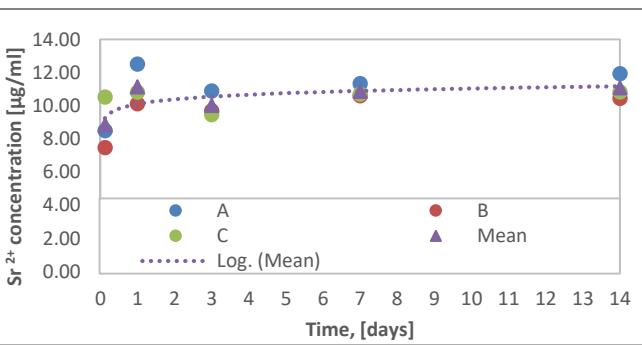
- **IV type isotherm**
- Surface area of **153 m²/g**.
- Pore size distribution **between 4 and 10 nm**.



The sample is **MESOPOROUS**

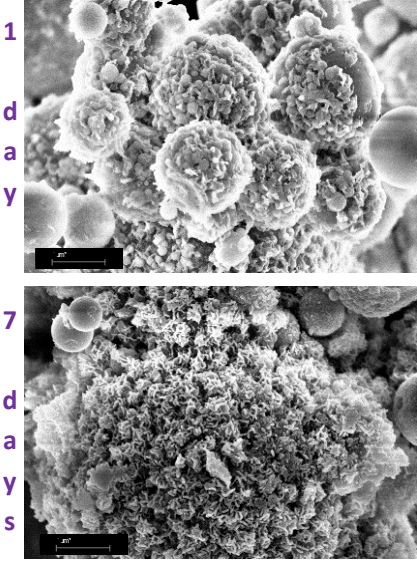


- **No peak** in the **VISIBLE** region
- **SD_SrMBG is white**
- **Peak at 200 nm** due to strontium



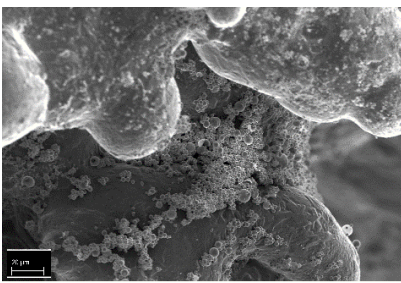
Strontium release: presence of an initial **burst release**. Final concentration of **11 μg/ml** ➔ osteogenesis [4]

Bioactivity test in SBF



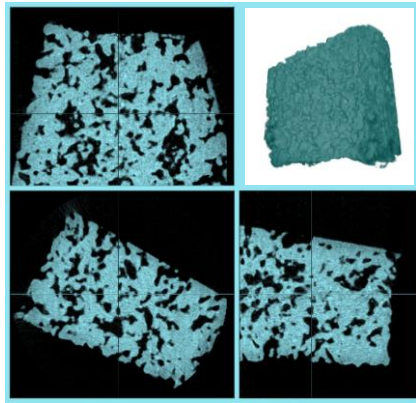
- **Fast bioactive behavior:**
- **After 1 day:** numerous **hydroxyapatite aggregates**.
- **After 7 days:** particles **completely covered** by a HA layer.
- **pH** always under value **7.8**
- value optimal for osteoblasts [5]

SCNA scaffold + SD_Sr-MBG

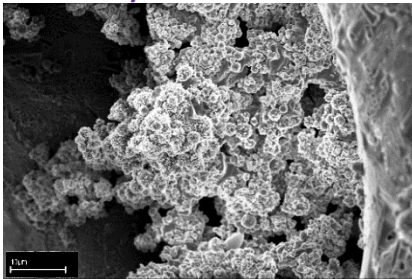


Abundant deposition on the pore wall, but not homogeneous. Best result at **150 V**.

MBG coating does not occlude the scaffold porosity, which is around **30%**.



Bioactivity test in SBF After 1 day



Numerous **HA aggregates**.
Scaffolds acquire a **fast bioactive behaviour**

Conclusions

MBGs synthesized with aerosol-based spray-drying process and doped with strontium have **excellent textural properties and a bioactive behaviour**. After electrophoretic deposition, they maintain these properties and consequently they **improve the bioactivity of SCNA scaffolds**, which initially are almost biologically inert. In this way we demonstrate that it is possible to obtain a **successful construct** for bone tissue engineering with both **excellent regenerative and mechanical properties**.

Acknowledgement

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www.mozartproject.eu

References

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